

A Novel Decision-Making Process for Tooth Retention or Extraction

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Background: Implant-supported restorations have become the most popular therapeutic option for professionals and patients for the treatment of total and partial edentulism. When implants are placed in an ideal position, with adequate prosthetic loading and proper maintenance, they can have success rates >90% over 15 years of function. Implants may be considered a better therapeutic alternative than performing more extensive conservative procedures in an attempt to save or maintain a compromised tooth. Inadequate indication for tooth extraction has resulted in the sacrifice of many sound savable teeth. This article presents a chart that can assist clinicians in making the right decision when they are deciding which route to take.

Methods: Articles published in peer-reviewed English journals were selected using several scientific databases and subsequently reviewed. Book sources were also searched. Individual tooth- and patient-related features were thoroughly analyzed, particularly when determining if a tooth should be indicated for extraction.

Results: A color-based decision-making chart with six different levels, including several factors, was developed based upon available scientific literature. The rationale for including these factors is provided, and its interpretation is justified with literature support.

Conclusion: The decision-making chart provided may serve as a reference guide for dentists when making the decision to save or extract a compromised tooth. *J Periodontol* 2009;80:476-491.

KEY WORDS

Dental implants; periodontal disease; tooth extraction.

Implant-supported prostheses have become the gold standard for the treatment of total or partial edentulism in most clinical scenarios. Almost 50 years of biomaterials development, a deeper understanding of biologic determinants, and clinical research in implant dentistry have paved the way for the extraordinary success reported for this modality of dental therapy. When placed in an ideal position, with adequate prosthesis design and proper maintenance, implants can achieve a success rate of 97% to 99%, with an outstanding long-term functional performance.^{1,2} The level of advancement in this field is such that dental implants, especially those with a rough surface,³ are a highly reliable option to replace single missing teeth and have the highest survival rates of all of the exogenous devices used in medicine.⁴ Given the increasing popularity and clinical success of dental implants, there is a tendency to believe that they are as good as natural teeth, if not better in certain clinical situations.

However, some would say that teeth are an irreplaceable gift from our parents. Tooth extraction and placement of a titanium implant is not always the solution when a tooth is compromised by periodontal, pulpal, traumatic, or carious pathology. Therefore, an increasingly frequent dilemma in implant dentistry derives from the question of whether to retain/restore a compromised tooth or to extract it and replace it with a prosthesis (i.e., implant-supported restoration

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or fixed partial denture).⁵ It is important to keep in mind that maintenance of the natural dentition in high function and acceptable esthetics remain the primary goals of any periodontal therapy. Prosthetic restorations cannot compete with a natural tooth with regard to the physical, biomechanical, and sensorial properties. Some of the main advantages of a tooth compared to an implant-supported restoration are the proprioception⁶ and the adaptation under mechanical forces^{7,8} mediated by the periodontal ligament.

However, the heroic maintenance of a tooth presenting a set of pathologic conditions that are beyond the scope of predictable dental practice may be associated with unfavorable consequences, such as a lack of function or extension of an odontogenic infection to craniofacial anatomic spaces.

The critical evaluation of factors that influence the clinician's decision about whether to save or extract a compromised tooth should be the cornerstone around which periodontology is built and certainly the basis of our profession as a medical discipline.

This article proposes a decision-making process that can assist clinicians in making the best decision to save or extract a tooth, based upon current available literature.

EXTRACT OR RETAIN A TOOTH? DECISION-MAKING CHART FOR EXTRACTION OR MAINTENANCE

When the decision whether to extract or retain a tooth has to be made, a large number of factors should be considered. In most cases, several treatment options may be adequate to successfully solve a particular problem. Understanding when to attempt to save and maintain a tooth and when extraction is indicated is an essential part of our clinical practice. Many articles published within the last 3 decades illustrate several criteria that clinicians may use to assess the tooth-related prognosis: the early report published by Becker et al.⁹ in 1984 to McGuire's¹⁰ 1991 prognosis classification and Kwok and Caton's¹¹ recent publication show the challenges associated with this decision.

We propose a chart to guide clinicians through the most significant factors that can influence the decision to save or extract an individual tooth based upon available current literature. Specialized scientific literature supporting the concepts proposed in our decision-making process was selected after performing a search in three databases (PubMed, Ovid, and Scopus) using MeSH and non-MeSH terms related to each category of the chart. To be included in the final selection, articles had to be published in English in peer-reviewed journals. No limitation with regard to the date of publication, type of article, and age of subjects was established. Book sources were also searched.

One particularity of our chart is the incorporation of a color-coded system (green, yellow, and red). Briefly, the green category suggests favorable long-term outcome if tooth saving is attempted, yellow means that saving the tooth could be tried (however, we have to proceed with caution because there is a factor that may or may not be properly controlled or eliminated), and red indicates a likely unfavorable long-term outcome if tooth retention is planned. To help clinicians make a better choice, we divided the factors and variables that can influence the final decision to save or extract a tooth into six levels: 1) initial assessment; 2) periodontal disease severity; 3) furcation involvement; 4) etiologic factors; 5) restorative factors; and 6) other determinants (Fig. 1). This decision-making chart should be interpreted level by level, starting at level one and continuing to level six. If a tooth receives at least three reds or two reds and at least two yellows in the same level, extraction is recommended. If the tooth receives two reds and one yellow, one red and at least three yellows, or four yellows, clinicians may attempt to save the tooth; however, extraction should be considered. For a tooth that has been assigned one red and up to two yellows, or three yellows, an attempt to save it is recommended; if it fails, extraction should be considered. In the case of two yellows, tooth maintenance may be compromised, but it is feasible. When a tooth is assigned green categories or one yellow, conservation is recommended because treatment often results in successful long-term tooth-survival outcomes. If a red category is accompanied by an asterisk (*), tooth extraction is strongly recommended.

Initial Assessment

Ideally, dental practice should be based on current clinical concepts emanating from science-based dentistry. Nonetheless, there are some factors that, given their nature, usually cannot be measured objectively but have a critical importance in the design of the treatment plan. These variables include patient expectations, finances, compliance, and esthetics. These factors are included in the first level of our decision-making chart to provide an adequate guideline when first approaching a situation in which a decision about extracting a tooth has to be made.

Patient expectations. When designing a dental treatment plan, one must consider more than clinical factors. The expectations of the patient have to be clearly identified and included as the main determinant in the decision-making process. For example, if a tooth is indicated for extraction after the initial clinical examination, but the patient shows a strong desire to save it, the option of keeping the tooth should be respected, although the patient should be made aware of the possible consequences and potential risks associated with this decision. Therefore, independent of the

EXTRACTION VERSUS CONSERVATION DECISION CHART

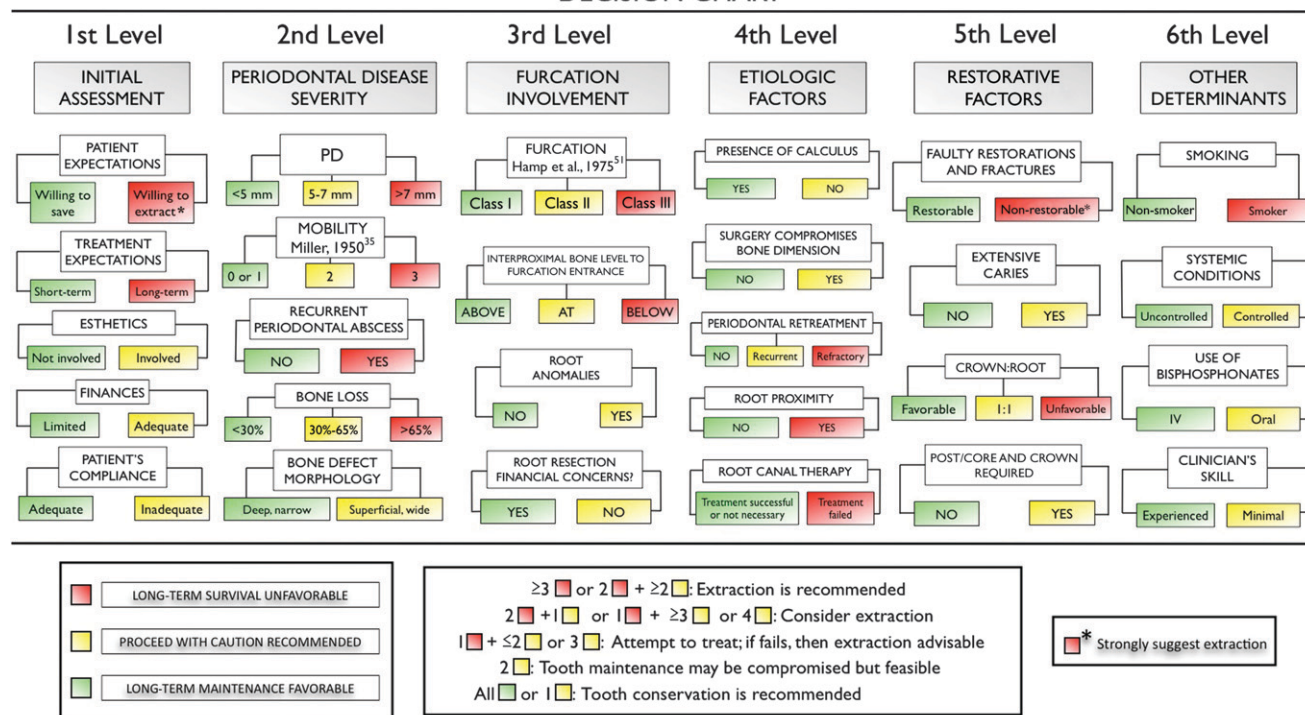


Figure 1.

Decision-making chart for tooth extraction or conservation.

particular significance of other important clinical factors that will be discussed in more detail, the patient's expectation is a major factor in deciding whether to extract or keep a compromised tooth.

Hence, if a patient is willing to save a tooth, retaining it has to be considered (green), whereas if a patient does not show special interest in maintaining a tooth or clearly desires its extraction, exodontia (red) may be the right option. This is one of the categories in which a red label is associated with an asterisk, which means that tooth extraction is strongly recommended.

Treatment expectations. The achievement of clinical outcomes compatible with a good long-term individual tooth/arch prognosis is one of the goals of any dental therapy. The strategic value of a particular tooth is an important parameter to be considered when designing a treatment plan. If retaining a tooth with reduced periodontal support is intended, one must remember that long-term maintenance under optimal conditions of function may not be realistic under certain circumstances. Also, if a restoration (i.e., implant supported) is properly developed after tooth extraction, according to the data from some prospective studies,^{12,13} the possibility of maintaining adequate long-term function is more feasible, even in patients with a history of periodontal disease.

Therefore, if a compromised tooth has to be assigned to extraction or retention, tooth conservation (green) may be suggested to the patient if treatment expectations are low in terms of durability (short-term). Conversely, if long-term results are expected and the tooth is compromised, tooth extraction (red) and prosthetic replacement may be a better option.

Esthetics. In current clinical practice, patients look for high-quality esthetic results, regardless of what kind of dental treatment is provided. Our patients demand treatment that includes proper function, health, treatment outcome stability, as well as appealing esthetics. In this sense, the smile is probably one of the most defining features of an individual and usually is the key to a beautiful face. The smile is constituted and defined by a set of elements that include the teeth (white component) and the gingival display (pink component), both framed by the lips. In a report on periodontal soft tissue augmentation, McGuire¹⁴ discussed the ideal esthetic features of the periodontal tissues. A correct symmetry of the papillary and free gingival margin component, adequate tooth emergence profile, and absence of discoloration are some of the most important parameters that define adequate esthetics. Esthetic guidelines are available and useful, but esthetics are a matter of perception,

highly determined by the interpretation of the observer, rather than a matter of health. Nonetheless, many severe non-esthetic gingival problems are caused by or coexist with periodontal pathologic conditions. In advanced stages of disease, many of the mucogingival or alveolar bone deficiencies are not predictably treatable and correctable from an esthetic standpoint. Therefore, if esthetics are not involved, the decision whether to conserve or extract a tooth becomes less critical (green); however, if saving a tooth implies keeping one with unsatisfactory esthetic conditions (long, discolored tooth) or the possibility that it may compromise future prosthetic esthetics, proceeding with caution is recommended (yellow), given our ability as clinicians to improve some esthetic problems related to natural teeth. In this case, the possibility of performing tooth whitening and soft/hard tissue-grafting procedures to pave the way for satisfactory esthetic outcomes may be explored.

Finances. The individual's financial status plays an important role in deciding the final dental treatment that one receives. Traditional restorative procedures or implant-supported restorations are usually more expensive than maintaining a tooth. Unfortunately, patients are not always aware of the additional cost, especially in the case of dental implants. Rustemeyer and Bremerich¹⁵ reported, after conducting a survey of 315 patients, that 61% had an unrealistic idea of the fees related to restorative therapy in which dental implants were used. For patients who cannot afford prosthetic therapy, saving/retaining a tooth in a compromised situation may be explored, as long as they accept that idea (green), whereas tooth extraction and replacement may be the right option when a tooth is indicated for extraction and finances are not an issue; however, proceeding with caution while considering individual socioeconomic variables is advised (yellow).

Patient compliance. It is widely accepted that pathogenic bacteria in a susceptible host are the primary cause of periodontal disease. The quantity of plaque and the etiologic potential of the microbiota present have an important impact on periodontal disease progression and, consequently, on the maintenance of periodontally treated teeth. A classic cross-sectional study,¹⁶ in which the periodontal condition of a Sri Lankan population was examined, demonstrated that some subjects who never received dental treatment had lost all of their teeth because of periodontal disease by 45 years of age. Nonetheless, another longitudinal study¹⁷ demonstrated that the incidence of caries, progression of periodontal disease, and tooth loss were very small in patients with a high level of compliance. This suggests that periodontal patients included in a regular periodontal maintenance program, who also have good oral hygiene, may have a

better individual tooth prognosis than non-compliant patients. Considering this information, it seems logical to say that patients who are genetically determined to be susceptible to periodontal disease, coupled with poor compliance, may have a lower chance of keeping their teeth long-term. This, in turn, reduces tooth survival dramatically given the presence of plaque in a susceptible host. Furthermore, one has to keep in mind that bacterial plaque also plays a major role in the development of peri-implantitis. Dental implants, like natural teeth, are also affected by plaque in susceptible individuals, although the pathophysiologic mechanisms are not exactly the same. Some longitudinal studies^{18,19} showed how the progression of plaque-induced bone loss seemed to be similar around natural teeth and implants. Poor plaque control and smoking have been strongly associated with implant failure and the development of peri-implantitis.²⁰⁻²²

Many ways to assess hygiene performance have been proposed.²³⁻²⁵ Some indices are visual, whereas others are expressed as a percentage, but all of them were designed as a method for recording plaque control and, therefore, the patient's ability to perform good oral hygiene. Regardless of the method used to assess the patient's compliance, when a patient cannot meet adequate standards of oral hygiene, the success of periodontal therapy and long-term tooth survival are often challenged.

Hence, although the presence of periodontal disease is mainly determined by susceptibility, long-term tooth conservation can be more reliably attempted in patients presenting an adequate level of oral hygiene (green), in contrast to patients showing poor compliance. Nonetheless, tooth extraction and implant placement may not be the best therapeutic approach in all patients; thus, proceeding with caution is recommended (yellow) given the uncertain therapeutic outcomes associated with elevated plaque scores and the variability in disease severity that depends on several other major risk factors (e.g., smoking and diabetes mellitus).

Periodontal Disease Severity

Treatment of periodontal disease is a therapeutic process with the goal of preserving the natural dentition in conditions of health and preventing further periodontal destruction. Nevertheless, the severity of a periodontal problem is such that tooth extraction should be considered one of the treatment modalities to resolve the problem. The interpretation of the most commonly used clinical parameters to determine periodontal disease severity is approached in this level.

Probing depth (PD). One way to assess periodontal disease severity is by measuring PD. In general, deep PDs with bleeding on probing are an indicator of

periodontal disease activity, as well as a predictor of future attachment loss, except in situations of pseudo-pocket formation or gingival overgrowth. The existence of a true periodontal pocket ≥ 5 mm usually implies a history of periodontal disease in that particular location.²⁶ PD is measured as the distance from the free gingival margin (FGM) to the bottom of the sulcus/pocket. However, PD may not be a reliable parameter for periodontal diagnosis, because it may change over time, even in untreated areas, as the result of changes in the vertical position of the FGM,²⁷ which was originally explained by Stanley²⁸ as inflammatory cycles and spontaneous resolution. However, following initial therapy, PD is regarded as the most reliable predictor for future disease progression, because deeper pockets are more susceptible to further periodontal breakdown.²⁹ Therefore, the evaluation of PD may be a good indicator to determine whether to extract an affected tooth. Longitudinal studies^{9,30} showed that recurrent deep pockets suggest a worse prognosis; therefore, tooth extraction may be considered in more severe, untreatable situations, such as PD >7 to 8 mm.

We divided this category into PD <5 mm (green), PD of 5 to 7 mm (yellow), and PD >7 mm (red) to illustrate our ability to maintain teeth with these different PDs.

Mobility. Tooth mobility is one of the most widely used periodontal parameters to determine individual tooth prognosis;¹¹ however, it may be not totally reliable. Although many investigators^{31,32} found that increased mobility is a factor that negatively influences the survival of a periodontally affected tooth, others³³ described no association between tooth mobility and treatment outcome. These differences could be explained by the cause of tooth mobility (i.e., loss of periodontal attachment or excessive function) and the use of different methods to assess tooth mobility. As proposed by Mühlemann,³⁴ mobility should be measured by using two rigid instruments to record the magnitude and direction of movement of a tooth after applying a force of ~ 100 g. In our proposed decision-making chart, we divided mobility into 0 or Class 1 (green), Class 2 (yellow), and Class 3 (red), based on the classic, widely used classification of Miller.³⁵ Basically, Class I indicates mobility greater than normal, Class II means tooth mobility up to 1 mm in any direction, and Class III is assigned for teeth presenting mobility >1 mm in any direction, including vertical displacement and/or rotation. In general, teeth exhibiting Class III mobility as the result of periodontal attachment are indicated for extraction because of their poor prognosis and likely patient discomfort.⁹ Teeth with a mobility of Class II should be evaluated in conjunction with other factors to determine the most predictable approach to treat that condition

(e.g., splinting in case of secondary trauma from occlusion or periodontal regeneration); hence, a yellow category was assigned. In addition, it is important to keep in mind that teeth have a slight degree of physiologic mobility, which may vary at different stages of life or even at different times during the day.³⁶ Furthermore, it is well known that single-rooted teeth usually present more mobility than multirooted teeth, and that mobility mainly occurs in a horizontal dimension.³⁷ This should be considered during the diagnostic process.

Recurrent periodontal abscess. Periodontal abscess represents a period of rapid clinical attachment loss and active bone destruction, and it is often considered when determining tooth prognosis. Periodontal abscess is the third most commonly reported dental emergency.³⁸ Tooth loss and spread of the infection are some of the consequences of this pathologic entity. Some investigators³⁹ reported that suppuration is the main clinical sign associated with tooth extraction during the maintenance phase. A hopeless prognosis is usually assigned when a history of repeated periodontal abscess formation is observed in a tooth.^{9,40,41} In a retrospective study⁴² of a maintenance population, 45% of teeth with periodontal abscesses were extracted.

Hence, in our chart, we divided this category into no suppuration (green) and the presence of suppuration (red) to represent the possibilities of successful tooth maintenance with this clinical scenario.

Bone loss. Bone loss is another one of the major factors used to determine tooth prognosis. Bone loss often leads to tooth mobility, increased PD, and subsequent clinical attachment loss. Periodontal bone loss is usually determined by radiographic analysis. Periapical radiographs, bitewings, and occlusal radiographs are classic bidimensional radiographic modalities that can serve as an adjunct to the periodontal clinical examination because they can provide a huge amount of valuable information by a relatively non-invasive method. Among these techniques, periapical radiographs probably represent the most widely used images in the diagnosis of periodontal diseases. The calculation of the percentage of bone loss is usually performed in a periapical radiograph by comparing the total length of the root from the cemento-enamel junction to the apex minus ~ 2 mm (for the biologic width) to the length of the root supporting alveolar bone.

In our decision-making chart, we divided alveolar bone loss into three categories: $<30\%$ (green), 30% to 65% (yellow), and $>65\%$ (red). The rationale behind this categorization was the fact that $<30\%$ bone loss can be properly treated and maintained.^{43,44} When bone loss of 30% to 65% is found, a significant attachment loss is often noticed. Nonetheless, studies⁴⁵⁻⁴⁷

indicated that teeth presenting this amount of bone loss also could be adequately treated and maintained over a long period of time. Bone loss >65% often implies that more than two-thirds of the periodontal support around the root surface has been lost. Although a tooth presenting that amount of bone loss could be maintained with proper supportive treatment, the likelihood of keeping such a compromised tooth over a long period of time is questionable. This is supported by the information presented by Becker et al.,⁹ who listed this condition as one of the eight criteria to indicate whether a tooth should receive a hopeless prognosis. However, it is important to keep in mind that radiographic images alone do not provide conclusive diagnostic evidence. Some of the shortcomings of radiographic assessment of periodontal bone loss are the possible angulation changes that may provide a distorted bone height and the inability to evaluate buccal/lingual bone.

Bone defect morphology. Periodontal bone loss can be divided into two patterns of bone destruction: horizontal and vertical. If bone loss progresses evenly around the dentition, the end result is a horizontal pattern of bone loss. A vertical defect is typically present in localized areas where the loss of alveolar bone progresses at different rates around tooth/teeth surfaces. Vertical bone loss may result in deep, localized narrow intrabony defects. This type of defect was shown to be more favorable for attempting regeneration in general.⁴⁸ If a patient presents generalized or localized horizontal bone loss, periodontal attachment gain via regenerative procedures, such as guided tissue regeneration, is unpredictable. This is mainly because the defect is not self-contained. On the contrary, a vertical defect provides the possibility of regenerating already destroyed tissues, following the principles of compartmentalization.⁴⁹ In addition, after initial therapy, the most common surgical approaches used to treat periodontal pockets associated with horizontal bone loss are resective procedures, such as gingivectomy or apically positioned flap with or without osseous recontouring, which often create esthetic concerns, tooth hypersensitivity, and challenging maintenance. Therefore, we subclassified this category into deep, narrow alveolar bone defects (green) and superficial, wide defects (yellow).

Furcation Involvement

In the third level, we focus on how furcation involvement may influence the clinical decision to extract or save a particular tooth. Furcation invasion is commonly associated with alveolar bone destruction and loss of attachment. Hence, furcation defects are regarded as one of the most clinically challenging periodontal pathologic conditions in our specialty because of their morphology, access, and many

anatomy-related abnormalities. Therefore, to treat this problem properly, local anatomic factors, such as cervical enamel projections, accessory canals, root concavities, root proximity, varying root trunk length, and root form, must be controlled.

Furcation defects. The furcation is that part of a multirooted tooth where the root cones separate. Given the intricate anatomy commonly present in association with this area, once the progression of periodontal disease reaches the furcation, treatment or maintenance may be challenging.⁵⁰ In our decision-making chart, we classified the furcation involvement into Class I (green), Class II (yellow), and Class III (red), following the classification proposed by Hamp et al.⁵¹ in 1975. Basically, Class I is assigned when the furcation has <3 mm of horizontal penetration when probed; Class II means >3 mm of horizontal penetration into the furcation area, but not through and through probing; and Class III indicates a through and through horizontal penetration of the probe. There is no doubt in every practitioner's mind that a Class I furcation defect can be properly treated and maintained. The risk for disease progression in a patient presenting a surgically created (osteoplasty/odonto-plasty) Class I furcation defect is minimal to zero, as long as the maintenance is adequate.^{52,53} In cases of Class II furcation defects, the treatment decision becomes more uncertain. Although it was shown that this type of defect can be successfully treated by regeneration and maintained over a long period of time,^{54,55} the predictability related to the type of treatment remains a major issue.⁵⁶ Therefore, proceeding with caution is definitely advised. Finally, it has been consistently shown that, in general, teeth with Class III furcation involvement have a bad prognosis. As reported in some studies,^{57,58} regeneration of this type of defect is not predictable in most clinical situations. Tunneling has been proposed as a conservative alternative in cases of Class III furcation involvement; however, long-term survival after treatment is not ensured because many complications associated with this condition (among which root caries predominates) may arise, compromising tooth prognosis.⁵⁹ Therefore, teeth with Class III furcation involvement have an unfavorable prognosis.

Interproximal bone level related to furcation entrance. According to our personal experience and information extracted from the literature, the level of the adjacent alveolar bone should be considered a critical factor when determining if regeneration of a Class I or II furcation defect can be attempted. In general terms, it is very unlikely to effectively induce periodontal regeneration above the actual alveolar bone level, representing the maximum level of regeneration that can be achieved in most clinical scenarios. Therefore, if the alveolar bone crest is located at or below a

furcation defect, it would be difficult or almost impossible to predictably regenerate bone to the original level.^{60,61}

Hence, in our decision-making chart we divided interproximal bone level as related to the furcation entrance into three categories, above (green), at (yellow), and below (red), to reflect how the adjacent bone level greatly influences our ability to regenerate furcation defects.

Root anomalies: Cervical enamel projections, enamel pearls, and root grooves. An important factor that may seriously hinder plaque control in furcation areas is the presence of non-cleansable root surface irregularities or anomalies, such as cervical enamel projections, enamel pearls, and axially directed root grooves.⁶² Cervical enamel projections and enamel pearls are found more frequently in posterior teeth,^{63,64} whereas palatogingival grooves are more prevalent in upper lateral incisors.⁶⁵ It is also important to remember that Booker and Loughlin⁶⁶ noted the presence of a mesial root groove in 100% of the teeth from a sample of upper first premolars. Regardless of their location, these anatomic alterations often present a challenge during therapeutic or maintenance procedures.

We divided this category into the absence of these anomalies (green) and the presence of one or more of these tooth-shape alterations (yellow) because clinicians have a chance to properly control/eliminate these problems.

Root-resected molars. Root resection is the sectioning and removal of one or more roots of a multi-rooted tooth. It is a conservative therapeutic option indicated in some furcation defects, which is aimed at eliminating the cause, to provide a better environment and have a chance to maintain the tooth.

This option is commonly linked to financial issues. If a patient has limited financial resources, root resection is a more affordable option compared to implant therapy because it does not require as much of an economic investment. Furthermore, it was shown that root-resected teeth have good long-term survival rates. Fugazzotto⁶⁷ compared the overall survival rate of teeth with resected roots followed by restoration ($n = 701$) to implants placed after tooth extraction ($n = 1,472$) over a period of ≥ 15 and ≥ 13 years, respectively. Resection of the distal root of a mandibular molar demonstrated the lowest success rate (75%). All other success rates for various root-resected molars in function ranged from 95.2% to 100%. Lone-standing implants in second-molar positions demonstrated the lowest success rate (85%). All other implants used in molar positions demonstrated a success rate ranging from 97.0% to 98.6%. Cumulative success rates were 96.8% for root-resected molars and 97.0% for molar implants. It was concluded that molar root resection

and restoration or extraction with implant placement resulted in satisfactory clinical outcomes. However, previous studies^{68,69} showed that root-resected teeth present survival rates $\sim 85\%$ and 68% after 5 and 10 years, respectively. Therefore, it can be acknowledged that a tooth that undergoes root resection has less periodontal support and a less favorable prognosis than a healthy, non-treated one.

Hence, if finances are an issue and root resection is indicated, root resection could be suggested to the patient to maintain the natural tooth (green) and function at a lower cost. Conversely, when root resection is a possibility to treat a furcation-involved tooth, and there is no critical economic limitation, the option of tooth extraction and subsequent implant placement may be considered (yellow).

Etiology and Treatment Factors

To properly manage periodontal disease, the true etiology of the ongoing pathology needs to be identified and eliminated. This gives the body a chance for repair or regeneration of lost tissues. Hence, the fourth level analyzes some of the most important considerations in making a correct decision with regard to saving or extracting a tooth.

Presence of calculus. To successfully treat a periodontal defect, the first and most important step is to identify the etiology and adequately control it. Although plaque is the primary cause of periodontal disease in a susceptible host, many other systemic and local conditions have been identified as possible contributing factors in the progression of this pathologic process.⁷⁰ Most of these conditions and factors are discussed in other sections of this article; however, among the local factors that may contribute to the progression of periodontal disease, calculus is probably the most significant. Calculus, also known as tartar, refers to mineralized deposits on the teeth surfaces due to the persistent presence of plaque. Depending on its location, two type of calculus can be identified: supragingival and subgingival. It is widely acknowledged that subgingival calculus has a higher pathogenic potential. Although calculus does not produce disease by itself,⁷¹ its presence on a root surface is commonly associated with gingival inflammation. This is because calculus serves as a reservoir for periodontopathogenic bacteria and their by-products (e.g., leukotoxins and lipopolysaccharides). It was shown that a calculus/toxin-free surface is the key to achieving and maintaining health after periodontal therapy.⁷²

If an affected tooth has identifiable, controllable etiologic or contributing local factors, the chance of saving it is substantially increased. However, if a tooth has symptoms without a known etiology, the result of the treatment may be problematic. Therefore, as long as

calculus can be successfully eliminated when it is identified clinically or radiographically, it usually results in predictable periodontal treatment outcomes unless other significant factors are still present. Hence, we divided this category into the presence of calculus (green) and the absence of it (yellow); even if no calculus is identified, other factors can still be diagnosed and properly controlled to treat the disease.

Surgery compromises bone dimension. Osteotomy was introduced in the 1950s as a periodontal therapy modality. This technique evolved into what is called osseous resective surgery.⁷³ One of the indications of osseous resective surgery is pocket reduction by recontouring of the alveolar bone, which also allows better management and repositioning of gingival tissues. In cases of shallow or medium alveolar bone defects (<4 mm depth), resective surgery has been regarded as the most adequate therapeutic method to achieve stable periodontal pocket reduction compatible with health over time.^{74,75} Nonetheless, given the requirements necessary to correctly perform this technique in advanced forms of chronic periodontitis, where progression of the disease may result in the formation of negative architecture, a significant amount of bone typically has to be removed, usually leading to recession.⁷⁶ The extent of the possible outcomes may be anticipated by considering the gingival biotype and the thickness of the remaining supportive bone. Hence, more bone loss can be expected in patients with a thin gingival biotype and thin supporting alveolar bone after performing osseous surgery.

Clinical outcomes after extensive osseous resective surgery can result in patient dissatisfaction due to longer teeth appearance and a high chance of teeth hypersensitivity.⁴⁰ Therefore, if resective procedures to save a compromised tooth may limit proper implant placement or esthetic outcomes in the future, one should proceed with caution (yellow) before performing osseous recontouring. Conversely, if pocket reduction can be done without sacrificing an excessive amount of bone, particularly in the esthetic area, tooth maintenance is recommended (green).

Periodontal retreatment. The primary therapeutic goal when treating patients with a periodontal pathologic condition is arresting disease progression and eliminating inflammation. To achieve such objectives, identification of the etiologic factors and reducing them to allow repair/regeneration and maintenance of health are essential. The protocol suggested by the American Academy of Periodontology (AAP) for the treatment of gingival and periodontal diseases includes a variety of mechanical (i.e., hand or ultrasonic scaling), chemical (i.e., antibiotics or antiseptics), surgical, and regenerative procedures that may be applied, depending on the extent and pattern of attachment loss, anatomic varia-

tions, type of periodontal disease, and therapeutic objectives.⁷⁷ When periodontal stability has been achieved upon the completion of active therapy, follow-up periodontal maintenance visits should be performed at periodic intervals. Following the guidelines of the AAP, maintenance visits should include an update of the medical and dental history; evaluation of extra- and intraoral, periodontal, and dental tissues (including assessment of PD, recession, attachment level, bleeding upon probing, suppuration, and soft tissue contour and consistency); assessment of the oral hygiene status; and mechanical cleaning of plaque, biofilms, stains, and calculus. The local or systemic delivery of chemotherapeutics may be used as an adjunctive therapy for recurrent or refractory disease.^{78,79} It is not unusual to identify sites in which PDs increase progressively over time or even in a short period as the result of acute breakdown. Recurrent disease and refractory disease are two similar, but different, terms. Recurrent refers to a relapse of the disease as the result of inadequate therapeutic management or inadequate plaque control, whereas refractory periodontitis is a persistent disease with excessive attachment loss that did not resolve, even though the best therapy was provided, including clinician and patient efforts to stop disease progression. Rescue therapy is a clinical term for periodontal therapy conducted after the completion of initial active periodontal treatment, justified by the identification of a persistent or recurrent problem. If a periodontal defect was properly treated, but the result was not good, the second treatment may not result in the outcome that would be expected in cases of refractory periodontitis.⁸⁰ However, there is still a chance of controlling recurrent disease if the etiology is properly addressed.

No need for retreatment after initial periodontal therapy suggests that tooth maintenance can be reliably accomplished (green). The adequate treatment of recurrent periodontal disease, with the possibility of using adjunctive methods, may result in periodontal stability of the affected site, so proceeding with caution by giving a second chance is recommended (yellow). Conversely, improving the situation in cases of refractory periodontitis may represent a considerable challenge; consequently, tooth extraction must be considered (red).

Root proximity. Root proximity can occur in the presence of crowded teeth, “kissing roots” of adjacent teeth, and narrow (close) or fused roots. The importance of the degree of root proximity as a contributory factor in the progression of periodontal disease has been the subject of several studies published throughout the last decades. In an early article by Heins and Wieder,⁸¹ who analyzed 116 posterior interproximal sites, they reported that when the interradicular distance was <0.5 mm, no cancellous bone was observed

histologically, but a lamina dura. Moreover, if that distance was <0.3 mm, alveolar bone was not present. It was speculated that the absence of adequate bone support facilitates periodontal disease progression. In this sense, it was reported in a recently published longitudinal study⁸² that root distances <0.8 mm are a risk factor for alveolar bone loss. Given this information, it seems logical to think that root proximity can be a predisposing factor for the progression of periodontal disease. However, we should not forget about the impact of other significant factors, such as oral hygiene and the presence of plaque. In a prospective study of 400 subjects who underwent orthodontic treatment, Artun et al.⁸³ observed that root proximity (diagnosed radiographically as interradicular distance <0.8 mm) did not predispose to a more rapid periodontal attachment loss, mainly in anterior teeth. The population in that study may not be comparable to the one that Kim et al.⁸² evaluated, in terms of motivation and oral hygiene. If we consider all of these facts, it may be concluded that in some cases of root proximity, the absence of supporting bone may present a weak area, facilitating rapid attachment loss in the presence of uncontrolled periodontal disease. In the event that it is causing some type of periodontal pathology, the treatment of root proximity is not a simple procedure; most times it requires orthodontic treatment. Therefore, interpreting root proximity as an interradicular distance <0.8 mm, its absence is compatible with a favorable prognosis that invites tooth retention (green), whereas non-treatable root proximity is a situation in which tooth extraction (red) has to be considered if significant attachment loss is present.

Root canal therapy. Endodontic problems are commonly derived from untreated caries that progressed through the mineralized dental structures to the dental pulp, causing inflammatory reactions and/or pulpal infections. The occurrence of these events often requires root canal treatment to alleviate the symptoms associated with this pathology. Sometimes, the necessity of endodontic treatment may sway a patient to select implant placement instead of investing time and money in root canal therapy.

In general, root canal treatment that is done for the first time in a particular tooth has a higher long-term tooth survival rate.⁸⁴ In cases where retreated root canals are done, their survival rates are substantially lower. However, these rates are slightly lower than those for implant-supported single-tooth restorations.^{4,85} It is important to take into account the fact that implant-based therapy and root canal treatment are very different therapeutic options, given the variety of factors that can independently affect the diagnosis and outcomes of both modalities.⁸⁶

Some important factors have to be taken into account when analyzing the long-term survival of end-

odontically treated teeth, such as the type of restoration, the size of the periapical lesion (if present), and the skill of the operator. It has been reported that teeth with a fixed partial restoration (crown) have higher survival rates than those with composite or amalgam restorations.⁸⁷ Also, the absence of periapical lesions or the presence of smaller ones have a better prognosis than larger lesions in terms of the success of endodontic therapy.⁸⁸ The average survival rate of teeth endodontically treated by a general dentist is $\sim 89.7\%$ after 5 years; if the treatment is performed by a specialist, the success rate increases to 98.1% .⁸⁹ Another study⁹⁰ showed that the 10-year survival rate of teeth treated by root canals performed by residents was 85.1% . If a root canal-treated tooth presents persistent symptoms, retreatment of the affected tooth is a suitable option. However, the survival rate of retreated teeth is not as high compared to initial treatment,⁹¹ especially when extensive periapical lesions are present.⁹² Therefore, when should a root canal treatment be classified as failing? Considering the information outlined above, it is reasonable to state that a failing root canal treatment is one that presents persistent symptoms, even after retreatment and adequate restoration, or complications related to the endodontic treatment that make the tooth non-restorable (i.e., root fractures).

Hence, if no treatment is necessary or if root canal therapy is successful, that tooth should receive a good prognosis (green), whereas failing endodontic treatment should automatically be associated with compromised long-term tooth survival (red).

Restorative Factors

The fifth level of this decision-making chart includes restorative considerations. For a restorative procedure to be called successful, the involved tooth/teeth should have normal function and acceptable esthetics. There are many factors that should be analyzed, including caries, fractured/faulty restorations, crown/root ratio, and determination of the need for a post/core and crown.

Fractures and faulty restorations. Improperly contoured or overhanging restorations can act as plaque-retentive areas, causing iatrogenic inflammation and bone loss. An overhang is defined as an excess of dental restorative material extending beyond cavity margins. Amalgam overhangs have been associated with the progression of clinical attachment loss.⁹³ This clinical attachment loss can result from biologic width infringement, as a consequence of allowing plaque accumulation at the restoration margin and remodeling to establish a protective soft tissue zone. A study⁹⁴ demonstrated that the more severe the periodontal disease, the greater the role of the overhang. In addition, amalgam overhangs can cause a significant loss

of alveolar bone. However, the overhang width and patient age do not affect the significance of the detrimental effects of the amalgam overhang⁹⁵ because not every individual is equally susceptible to the development of periodontal disease. Therefore, it can be concluded that the presence of faulty restorations is not a determining factor in the decision-making process of extracting a tooth. However, it is important to evaluate the presence and its relationship to other factors, such as the presence of caries and/or endodontic involvement, before any decision is made. Also, it is extremely important to understand that overhangs can be corrected in most cases. The same line of thinking is applied to tooth fracture evaluation. If a tooth exhibits a fracture, the clinician should make his/her best judgment to determine restorability. If restoration is not possible, then a poor prognosis should be given.

Therefore, we divided this category into restorable (green) and non-restorable (red) to reflect the possibilities of saving a tooth. In the case of a non-restorable tooth, extraction is strongly recommended.

Extensive caries. Caries is a pathologic infectious process that affects the mineralized structures of the tooth, leading to loss of structure, pulpal sensitivity or pain, and eventually, if not properly treated, to endodontic problems and even tooth extraction. In this sense, recurrent caries associated with a fixed partial prosthesis is one of the most frequent causes of tooth loss. In a review published by Goodacre et al.⁹⁶ in 2003, the investigators analyzed the incidence of complications associated with single crowns, fixed partial dentures, all-ceramic crowns, resin-bonded prostheses, and posts and cores; the three most commonly reported complications for fixed partial dentures were caries (18% of abutments), need of a root canal treatment (11% of abutments), and loss of retention (7% of prostheses). An extensive carious lesion that extends beyond or to the level of the alveolar bone usually represents a challenge for the clinician in restorative terms and a substantial increase in treatment costs for the patient. If a tooth is restorable, orthodontic extrusion, crown lengthening, or mucogingival surgical procedures are usually necessary to respect the biologic width.⁹⁷

Hence, we divided this category into two options: no extensive caries present (green) and the presence of at least one extensive carious lesion in a particular tooth (yellow).

Crown/root ratio. Teeth that have not suffered any type of pathology involving loss of attachment or destruction of periodontal tissues usually present a favorable crown/root ratio. It has been speculated that the mobility of the tooth can be increased as a result of a biomechanical unbalance, known as secondary trauma from occlusion.⁹⁸ Symptoms and problems associated with secondary trauma from occlusion

can be treated effectively with splinting and occlusal adjustment in some cases.⁹⁹ However, the long-term maintenance of a tooth with an unfavorable crown/root ratio can be challenging because of inadequate alveolar bone support that may lead to increasing mobility and/or the persistence of clinical symptoms.^{100,101} Furthermore, when focusing on the field of restorative dentistry, a tooth with an unfavorable crown/root ratio may not be the ideal abutment tooth. A 1:1 ratio has been defined as the minimum acceptable ratio when the periodontium is healthy and the occlusion is controlled.^{102,103}

Hence, we divided this category into favorable crown/root ratio <1:1 (green), 1:1 ratio, which suggests proceeding with caution (yellow), and an unfavorable ratio >1:1 (red).

Post/core and crown required. In case of extensive loss of tooth structure, the use of post/core is one of the available options to allow proper crown restoration. This therapeutic approach has been classically regarded as a valid method for dental restoration; however, it has some drawbacks.¹⁰⁴ First, if not already present, root canal treatment is typically required. This reduces the long-term survival of the tooth as discussed in previous categories. The patient's occlusal scheme is another important factor to be considered. Parafunctional habits, such as bruxism, reduce the survival of teeth restored by post and core placement, because these teeth are weakened, especially if a post that is too large or wide is placed. In many of the teeth that are indicated to receive a post/core and crown, the length of the available tooth structure is usually insufficient to ensure biologic width preservation, and crown lengthening is often indicated. This makes the final cost similar, if not greater, to that of a single implant. Considering all of these factors, many patients, as well as clinicians, may decide to have the tooth extracted. To be realistic, the final decision is usually linked to financial issues and the concern for long-term stability as opposed to our ability to save a compromised tooth.

Therefore, we divided this category into no post/core and crown needed (green) and an indication for that type of restorative approach (yellow).

Other Determinants

The last level analyzes other factors that may play a significant role in tooth maintenance and prognosis or implant placement: smoking habits, presence of certain uncontrolled systemic conditions, the use of bisphosphonates (one of the most discussed topics in implant dentistry), and the clinician's experience.

Smoking. Smoking is a major risk factor for periodontal disease progression. The literature supports the fact that smokers have an increased risk (odds ratio: 2 to 8) for developing periodontal disease compared

to non-smokers.¹⁰⁵ It is known that the effect of smoking on the periodontium is dose dependent. Tomar and Asma¹⁰⁶ demonstrated that heavy and light smokers (≤ 10 cigarettes per day) have a 5.9 and 2.8 greater chance to develop periodontal disease compared to non-smokers, respectively. Tobacco smoking is responsible for some immune response alterations, causing impairment of the polymorphonuclear cells' viability and functions, reduced levels of immunoglobulin G, and inhibition and proliferation of B and T cells.¹⁰⁷ In addition, smokers have characteristics that may compromise wound healing, such as increased local vasoconstriction,¹⁰⁸ a higher proportion of neutrophil-released reactive oxygen species,¹⁰⁹ and a higher incidence of bacteria from the red complex.¹¹⁰ This information supports the notion that saving a tooth in smokers can be very challenging. Considering the success rate of dental implants in smokers compared to non-smokers, implant therapy may be a better option than keeping a compromised tooth.¹¹¹ A meta-analysis¹¹² evaluating the risk for implant failure demonstrated no difference between smokers and non-smokers as long as implants with a rough surface were used. Nonetheless, we have to consider that according to the data in a more recent review,²² smokers have a higher risk for developing peri-implant bone loss compared to non-smokers, regardless of the amount of cigarettes smoked daily. This should be considered when using implant-supported restorations to replace an extracted tooth in heavy smokers; however, the correlation between the number of cigarettes smoked and the severity of peri-implant bone loss has not been clearly established.

Based on all of this information, we divided this category into non-smokers (green), in whom the prognosis is favorable, and smokers (red), patients in whom long-term tooth maintenance is usually challenging.

Systemic conditions. Assessment of the general medical status of a patient is an absolute requirement before starting the clinical evaluation and developing a treatment plan. Several systemic diseases and medications are known to have a significant impact on periodontal disease progression and bone remodeling and determine periodontal/implant therapy indications and final outcomes. Conditions such as diabetes mellitus, immune depression (e.g., human immunodeficiency virus-induced acquired immunodeficiency syndrome), hematologic and genetic disorders (e.g., neutropenia and interleukin-1 polymorphisms), sex hormone disarrangements (e.g., osteoporosis), stress, and a plethora of medications (membrane-ion channel blockers, antiepileptic drugs, cyclosporin, nifedipine, and steroids) have been shown to contribute to the severity of some periodontal conditions.¹¹³ Other systemic problems, such as hypertension, history of prosthetic joint re-

placement, radio- or chemotherapy, and coagulation disorders, may influence surgical planning. Given their prevalence and/or impact on disease progression or therapy success, diabetes mellitus (type I or II), hypertension, and osteoporosis are probably the systemic conditions with the greatest importance in periodontal and implant dentistry practice. According to the guidelines established in the American Society of Anesthesiologists physical status (ASA-PS) classification proposed by the ASA, the patient's medical status should be evaluated prior to surgical intervention and proceed following the suggested protocol for each one of the six categories; in general terms, patients classified as ASA-IV, -V, or -VI are not to be treated in a dental office, and a medical consultation is advised for ASA-III uncontrolled conditions.¹¹⁴

We suggest that extracting a tooth and subsequent implant placement could be performed in the presence of a controlled systemic condition, but one should proceed with caution (yellow). If a patient has a systemic condition that is not properly controlled, tooth conservation is advised (green) because a surgical procedure may present an unnecessary risk for the patient.

Bisphosphonate use. Bisphosphonates represent a broad family of molecules, which are analogous to pyrophosphates. Their therapeutic use was proposed 4 decades ago, when Fleisch et al.¹¹⁵ pointed out the possibilities of these drugs. Each bisphosphonate has its own chemical structure according to substitutions at position R_1 and especially R_2 of the carbon atom; hence, each one has its own biologic behavior and pharmacokinetics.¹¹⁶ However, all bisphosphonates can exert two important biologic actions that produce a reduction in bone turnover: inhibition of mineralization and inhibition of bone resorption. These two properties allow the treatment of ossifying tumor-induced ectopic ossifications and calcifications,¹¹⁷ such as Paget's disease, and pathologic metabolic conditions in which bone turnover is unbalanced in favor of bone resorption, such as osteoporosis. The capacity of bisphosphonates as inhibitors of bone resorption was first observed in *in vitro* studies.¹¹⁸ It is known now that, at the cellular level, the osteoclast is the final target of the biologic action of bisphosphonates.¹¹⁹ Various mechanisms have been proposed to explain this reduction in the resorptive activity of osteoclasts, but only the capacity of bisphosphonates to shorten the life of osteoclasts and inhibit osteoblast recruitment and activity on bone surface have been demonstrated.¹²⁰⁻¹²² Nonetheless, the prolonged use of bisphosphonates was recently associated with the appearance of a pathologic condition affecting the jaws called bisphosphonate-associated osteonecrosis of the jaws (ONJ). The definition of ONJ as proposed by the American Society for Bone and Mineral Research is the "presence of

exposed bone in the maxillofacial region that did not heal within 8 wk after identification by a health care provider, in a patient who was receiving or had been exposed to a bisphosphonate and had not had radiation therapy to the craniofacial region.”¹²³ Since the first clinical reports describing ONJ,¹²⁴ many efforts have been made to increase our awareness of this disease. Although the treatment and exact pathogenesis of this condition is not clear, persistent bone necrosis seems to be related to the inability of bone to remodel after a significant trauma. This is because bisphosphonates inhibit osteoclastic function, which depletes the bone-remodeling capacity. However, not all patients taking bisphosphonates develop ONJ. It seems that the risk for ONJ is dependent on two factors: the type of bisphosphonate (oral or intravenous [IV]) and the duration of drug usage. The risk for ONJ associated with oral bisphosphonate therapy for osteoporosis seems to be low, estimated between 1 in 10,000 and less than 1 in 100,000 patient-treatment years. This may be higher when more information is available. Some of the most common oral bisphosphonates are alendronate, ibandronate, and risedronate. Conversely, the risk for ONJ in patients treated with high dosages of intravenous bisphosphonates ranges between 1 and 10 per 100 patients (depending on the duration of therapy). Pamidronate and zoledronic acid are two examples of regularly used IV bisphosphonates. The severity of ONJ induced by oral bisphosphonates is not as dramatic as in patients administered IV bisphosphonates because patients treated with IV bisphosphonates typically receive higher dosages.¹²⁵⁻¹²⁷ Also, the resolution of the lesions is more likely to occur with the use of oral bisphosphonates. Another important factor to consider is the duration of the bisphosphonate therapy; there seems to be an association between a higher incidence of ONJ and a longer duration of bisphosphonate exposure, empirically defined as >6 months for IV bisphosphonates and >3 years for oral bisphosphonates.¹²³

Hence, if a patient has received IV bisphosphonates, a conservative non-surgical approach is strongly recommended; therefore, tooth conservation is advised (green). Because the risk for developing ONJ seems to be lower in patients taking oral bisphosphonates, proceeding with caution is advised if any surgical dentoalveolar procedure is indicated (yellow), especially when the patient has been taking the drug for >3 years.

Clinician's skill. Dental professionals should seriously consider the individual decision of whether to extract or save a tooth. Some studies^{128,129} reported that the clinician's experience is not a major factor influencing the survival rate or ideal implant placement, using a conventional flap or flapless technique. However, we believe that when it comes to making the

final decision of whether to extract or maintain a compromised tooth, the level of experience and skill of the clinician is an important factor to be considered. An inadequate indication for extraction has been mentioned as the third most common reason for tooth loss.¹³⁰ This may be explained by the fact that if a clinician believes that he/she is unable to save a tooth, tooth extraction and future prosthetic replacement will most likely be recommended.

Therefore, we divide this category into experienced clinicians (green) and clinicians with minimal experience (yellow), in terms of the ability for a dental professional to treat and save a compromised tooth.

DISCUSSION

It was the goal of this article to address and discuss most of the important factors that might influence the crucial decision to save or extract a tooth. To properly interpret the decision-making chart and make it easy to apply, several aspects discussed below must be considered.

This chart was created for individual tooth prognosis. It was not designed to consider the overall prognosis from a strategic standpoint. Nonetheless, it is important to keep in mind that an individual tooth's fate is often influenced by the final overall treatment plan that involves the whole dentition.

Some of the categories in the first and the sixth level are subjective, with all of the implications that this may have.

Genetic determinants and age were not included in the decision-making chart; however, they should be considered together with other factors when making the decision. For example, aggressive forms of periodontal disease should be evaluated from different perspectives, especially with regard to plaque control and the patient's genetic susceptibility. This chart is mainly oriented to evaluate cases in which periodontitis is present in a chronic form. Therefore, in cases of aggressive periodontitis, we suggest following AAP guidelines for its treatment.

Finally, we understand that no guide designed to aid in the decision to extract or save a compromised tooth can be perfect. It is the responsibility of the clinician to make the final decision by considering the factors outlined in the chart together with other specific aspects of each case.

CONCLUSIONS

The retention of a restored or periodontally compromised tooth, as opposed to tooth extraction and subsequent prosthetic replacement, is one of the most difficult and multifactor-dependent decisions that dental professionals must make. Different factors associated with a compromised tooth may play a role in this complex process. We have attempted to list all of

the significant factors and provide a rationale of how we used these criteria in making the decision to save or retain a tooth. All of these factors have to be weighed and analyzed before a decision is made. There are no absolutes or universal rules that can be applied to every case. Clinicians may make a sound clinical judgment by referring to this decision-making chart, but it is important to understand its limitations and the random involvement of some risk factors. The experience and clinical criteria, along with the common sense of the professional, are still the most important tools available to be used as a guide in deciding whether to extract or retain a tooth.

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